Pion-Proton femtoscopy in STAR experiment

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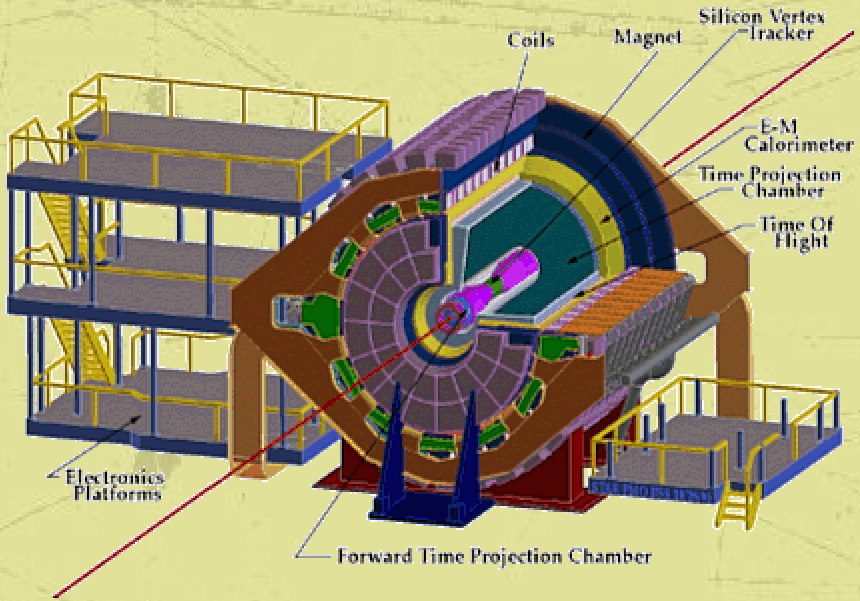
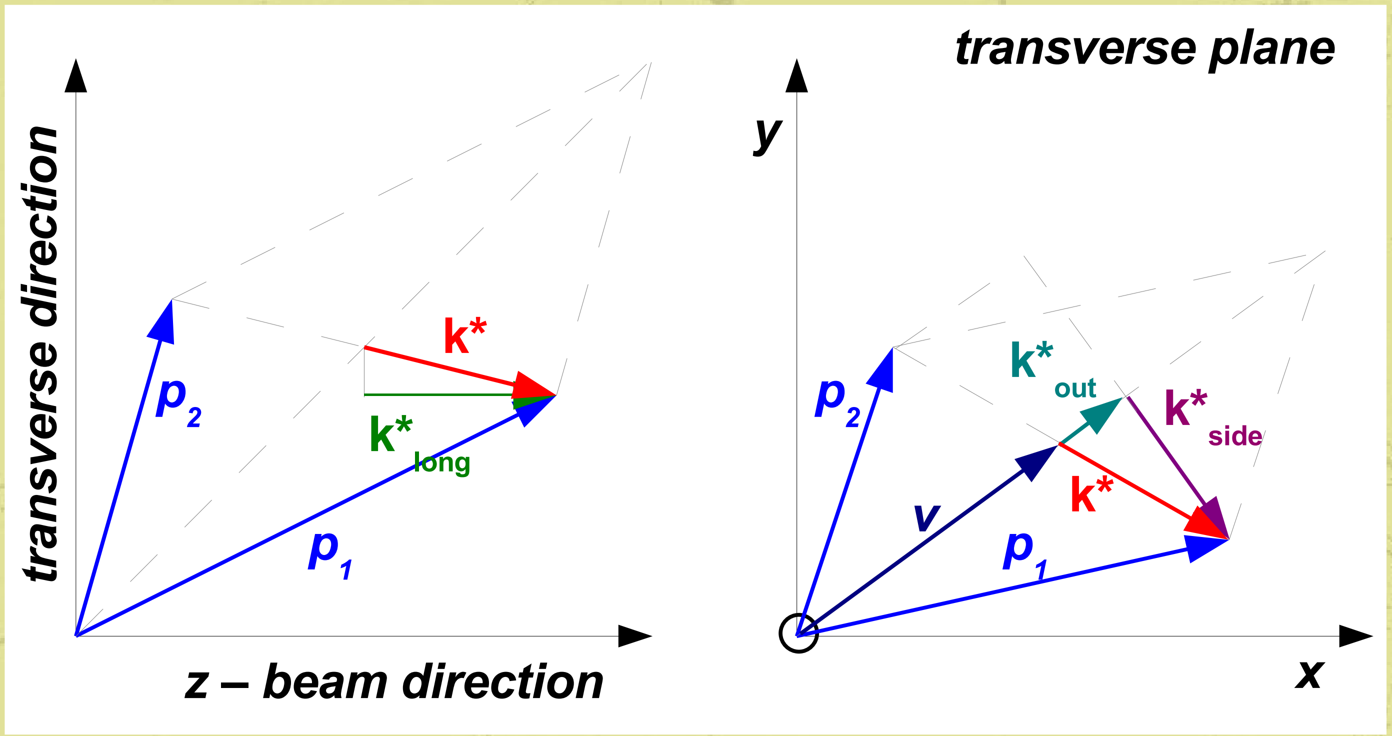
Outline:

- Physics motivation:
  - Space - time emission asymmetry measurement
  - Final State Interaction study (coulomb and strong)
- Data selection:
  - events,
  - particle identification,
  - detector effects.
- Results for Au+Au 200AGeV
  - correlation functions for π-p,
- Blast-Wave & Therminator
- Conclusions



Decomposition of $\vec{k^*}$ vector



k* - momentum of the first particle in the PRF

PRF – Pair Rest Frame – frame where the center of mass of the particular pair is at rest.

LCMS – Longitudinally Co-Moving System, where $p_{1,z}=-p_{2,z}$, and velocity of the pair $\beta_z = \frac{|p_t|}{E^2 - p_z^2}$

Selection the first particle is arbitrary and influences the sign of the measured asymmetry. In our analysis pion is always taken as a first particle

k^*_{long} – parallel to the beam direction – z

k^*_{out} – parallel to the pair momentum

k^*_{side} – perpendicular to k^*_{out} and k^*_{long}

FSI as an origin of asymmetry

$$CF = A_C(k^*)\left[1 + 2\langle r^*(1+\cos\theta^*)\rangle / a_c + \ldots\right]$$

Gamov factor

Source of the asymmetry

Bohr radius
for π–p a_c=±222fm

For pion-proton system only coulomb interaction plays significant role.

k*- **half of the relative momentum**
momentum of the first particle in PRF
r* **- separation between emission points**
θ* **- angle between *k** and *r** vectors**

Correlation is stronger when *cosθ*<0* – *k and *r** are anti-aligned and weaker when *cosθ*>0* – *k** and *r** are aligned.**

Asymmetry measurement

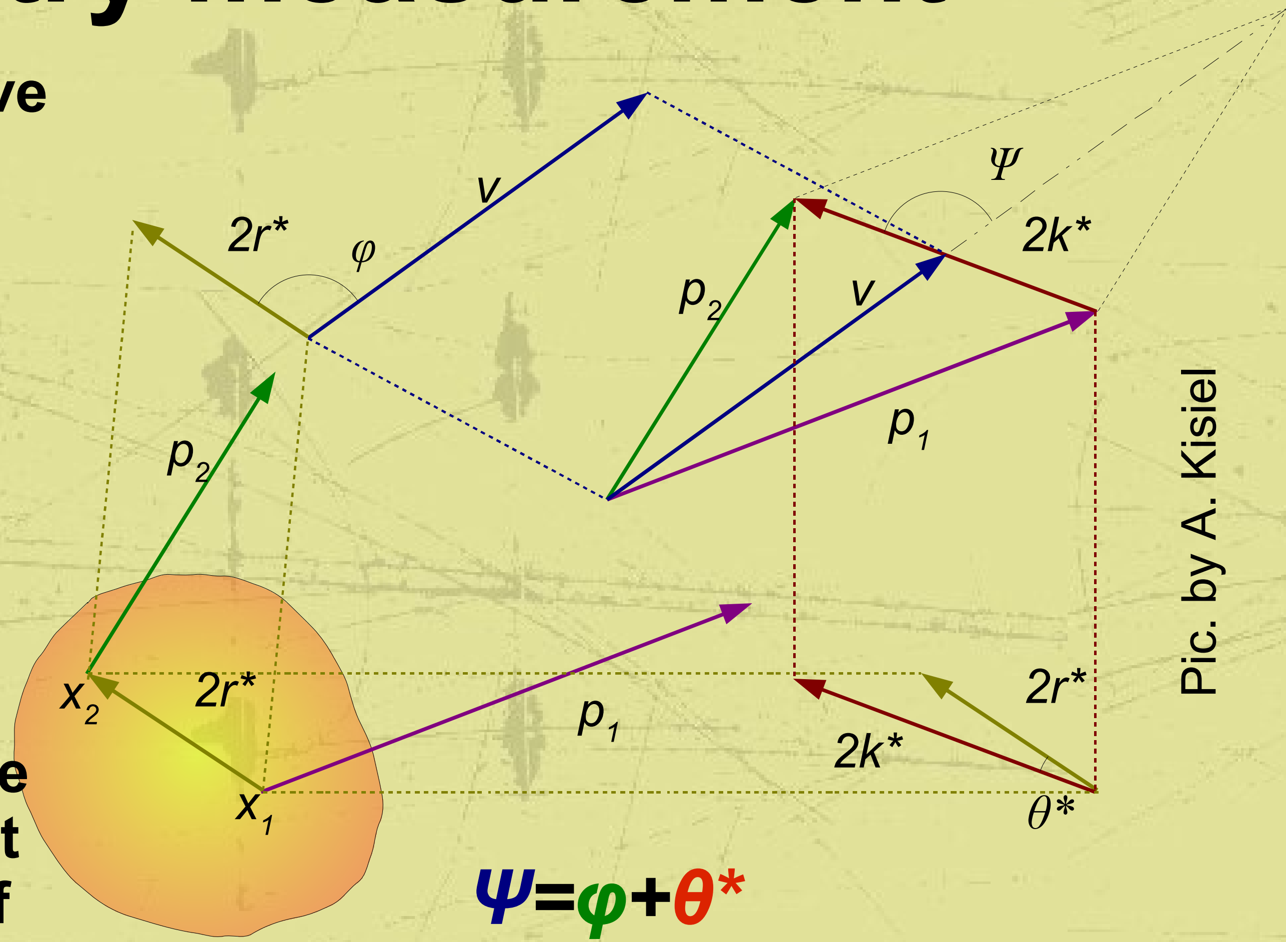
From the experiment we have sign of the *cos(Ψ)*, so we calculate CF for two groups of pairs:

$\cos(\Psi)>0$ (C^+)
$\cos(\Psi)<0$ (C^-)

If $C^+>C^-$ then $\langle\cos(\varphi)\rangle<0$

If $C^+<C^-$ then $\langle\cos(\varphi)\rangle>0$

"double ratio" C^+/C^- **- gives us information about relative orientation of r* with respect to v and about magnitude of <r* || v>.**



Pic. by A. Kisiel

$$\Psi=\varphi+\theta^*$$

$$\mathrm{sign}\langle\cos(\Psi)\rangle=\mathrm{sign}\langle\cos(\theta^*)\rangle\,\mathrm{sign}\langle\cos(\varphi)\rangle$$

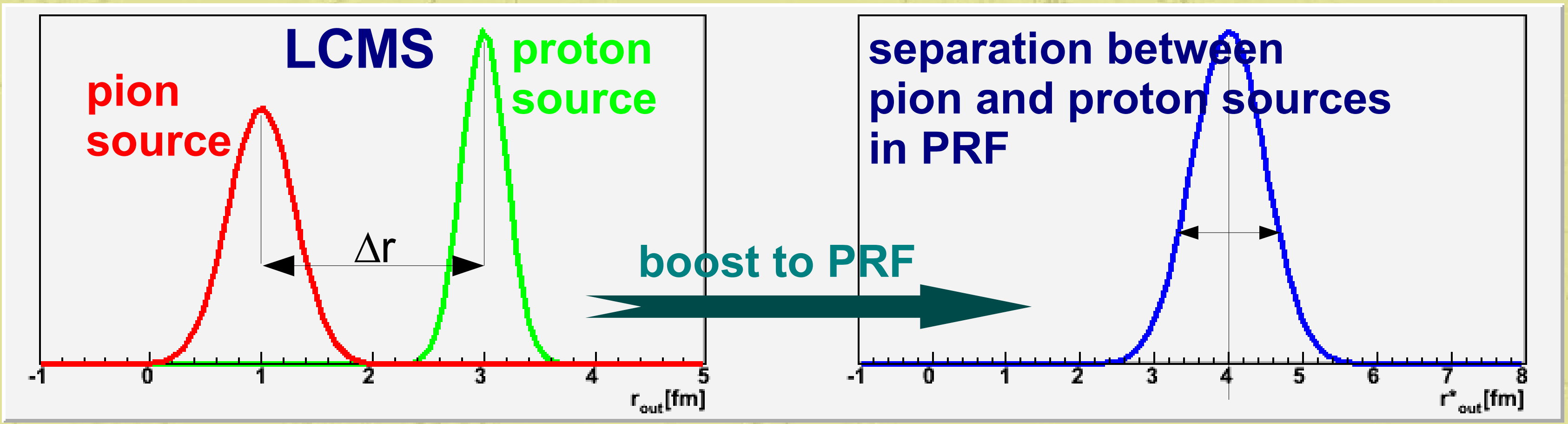
This we measure in the experiment

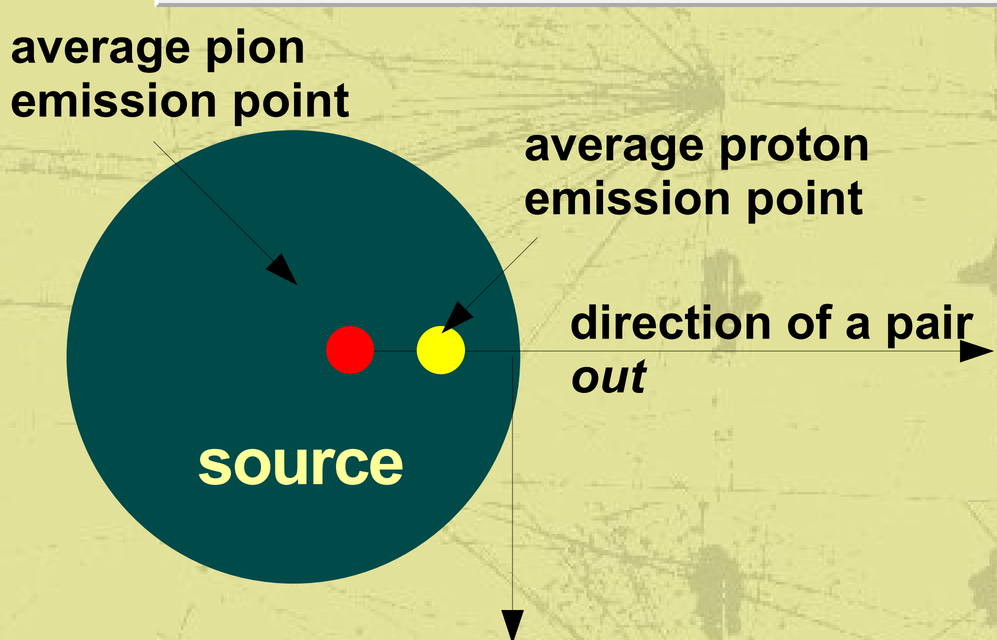
This is the origin of emission asymmetry

And this is the result of our analysis

R.Lednicky, V. L.Lyuboshitz, B.Erazmus, D.Nouais, Phys.Lett. B373 (1996) 30.

Observed asymmetry





side **direction – sign arbitrary.**
We do not expect any asymmetry in this direction.

$$\sigma_{\pi p} = \sqrt{\sigma_{\pi}^2 + \sigma_{p}^2}$$

Observed separation in PRF comes from

- **space asymmetry (flow)**

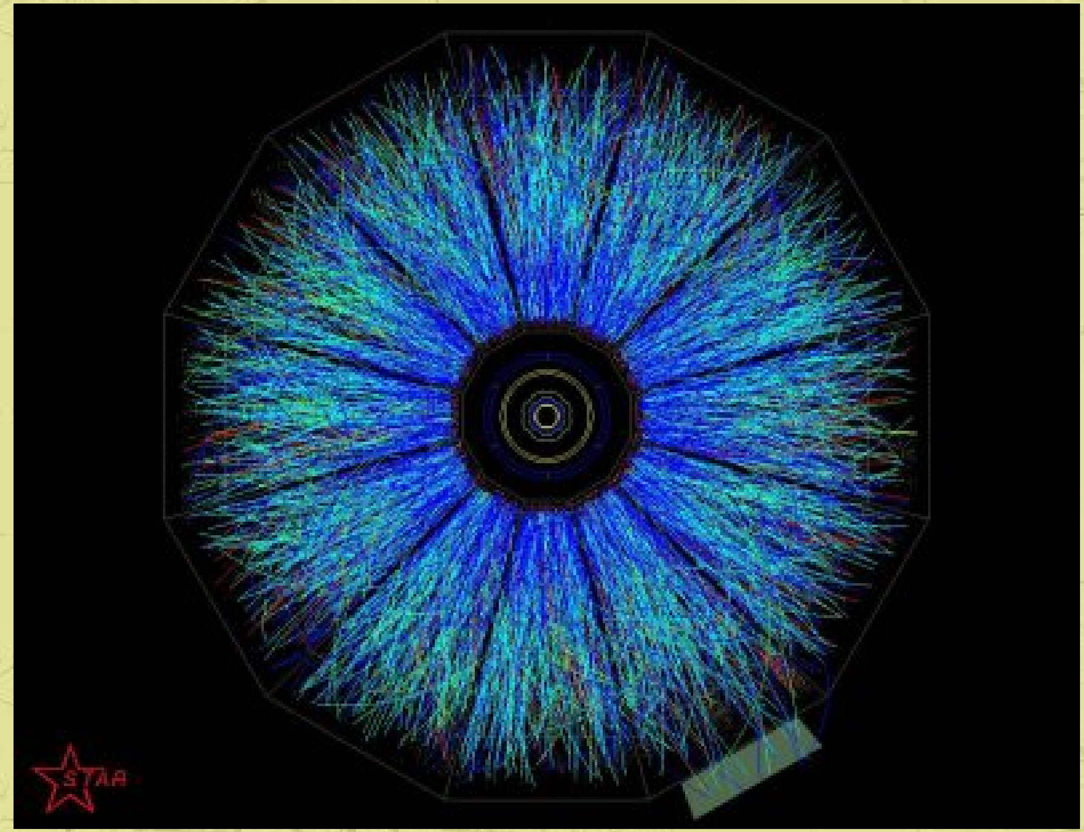
and from

- **emission time difference**

$$\langle r^* \rangle = \langle \gamma_T (\Delta r - \beta_T \Delta t) \rangle$$

Data analysis

- Au+Au collisions at $\sqrt{s_{NN}}$=200GeV
- Events:
  - central (0-10%)
  - mid-central (10-40%)
  - peripheral (40-80%)
  - zvertex position ±30cm from the center of TPC

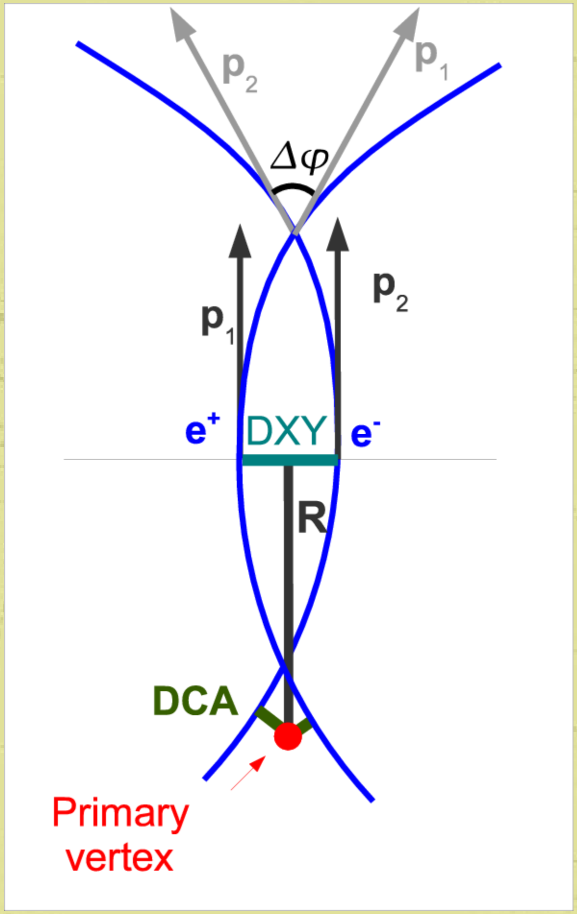


Data analysis

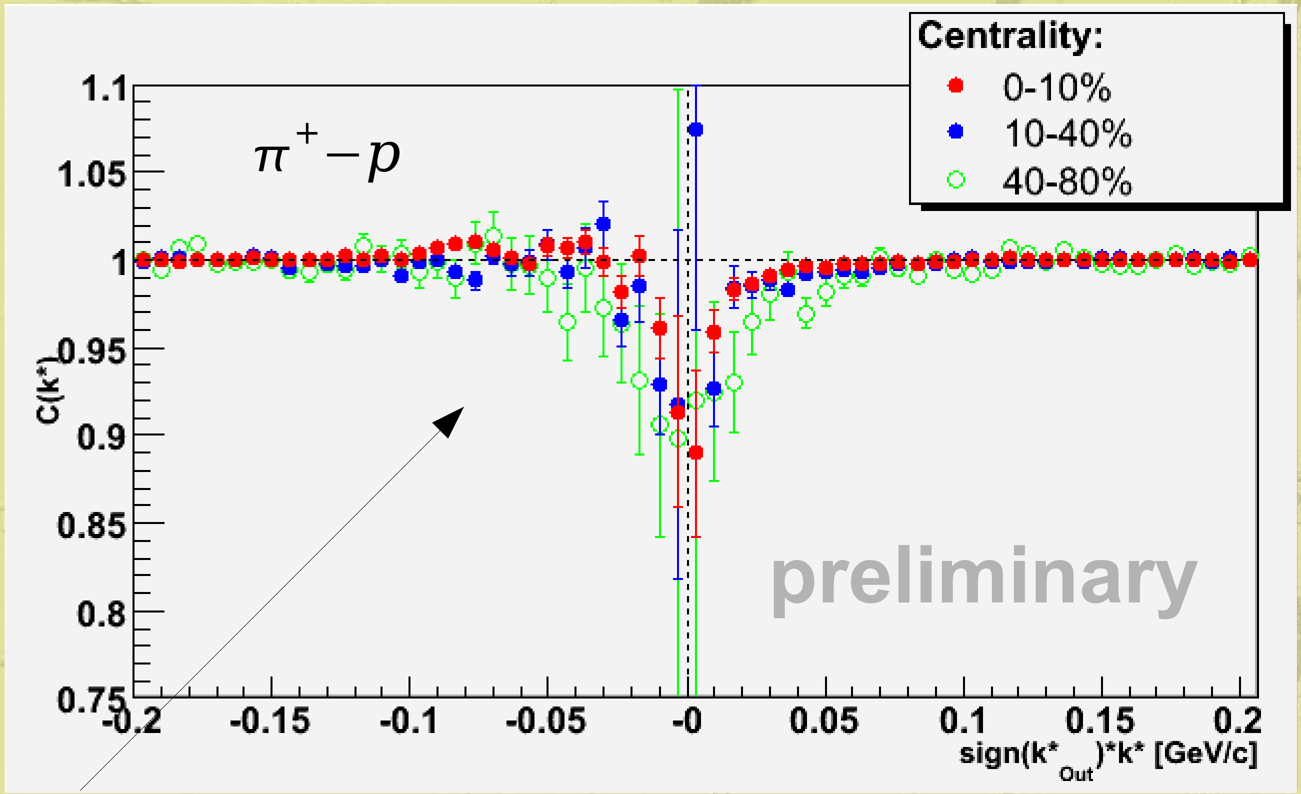
- Single track level cuts (pions, protons)
  - dE/dx identification

	π	**p**
p [Gev/c]	0.11-0.5	0.3-1.25
p_T [Gev/c]	0.1-0.5	0.3-1.25
y	±0.7	±0.7

- Pair level cuts:
  - pairs with merged hits of tracks
  - electron-positron pairs from gamma conversion (advanced topological cut)
  - non π-p pairs

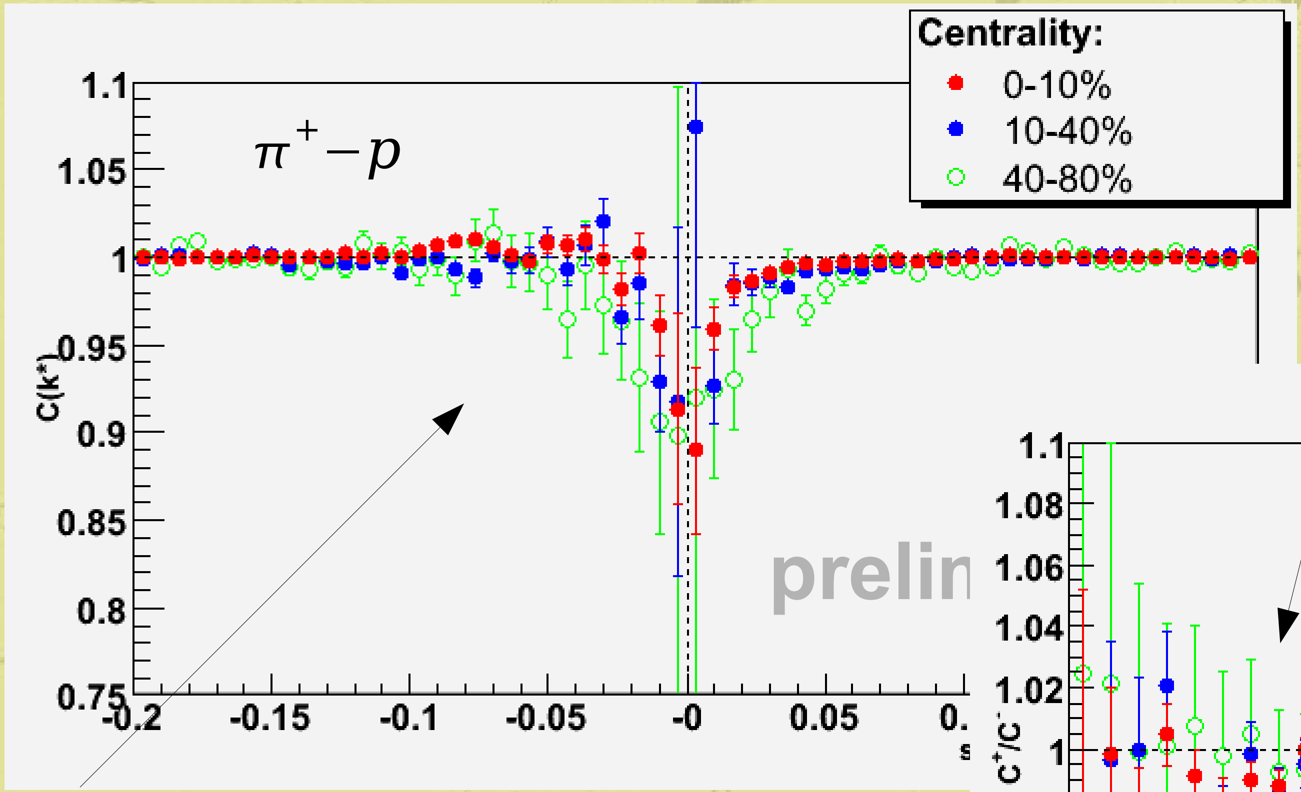


π-p correlation functions like sign pairs

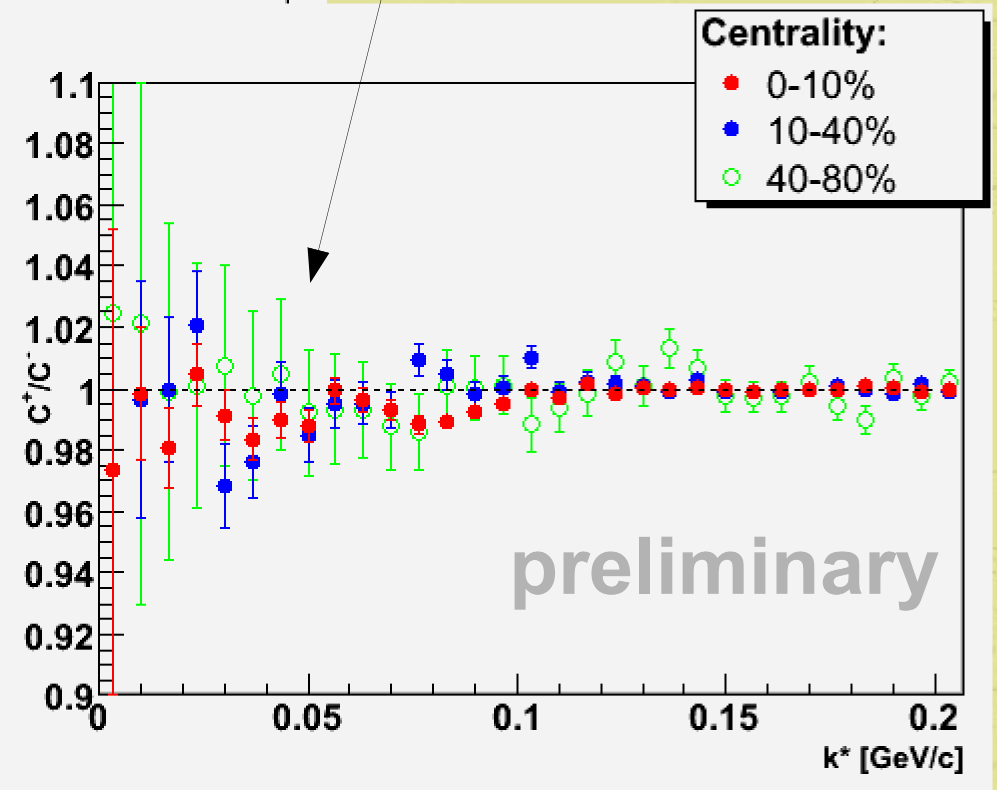


FSI for pion-proton in the region of low k* is dominated by Coulomb interaction. For like sign pairs correlation effect is negative.

π-p correlation functions like sign pairs



Deviation from unity in “double ratio”. Proton source is relatively shifted to pion source.



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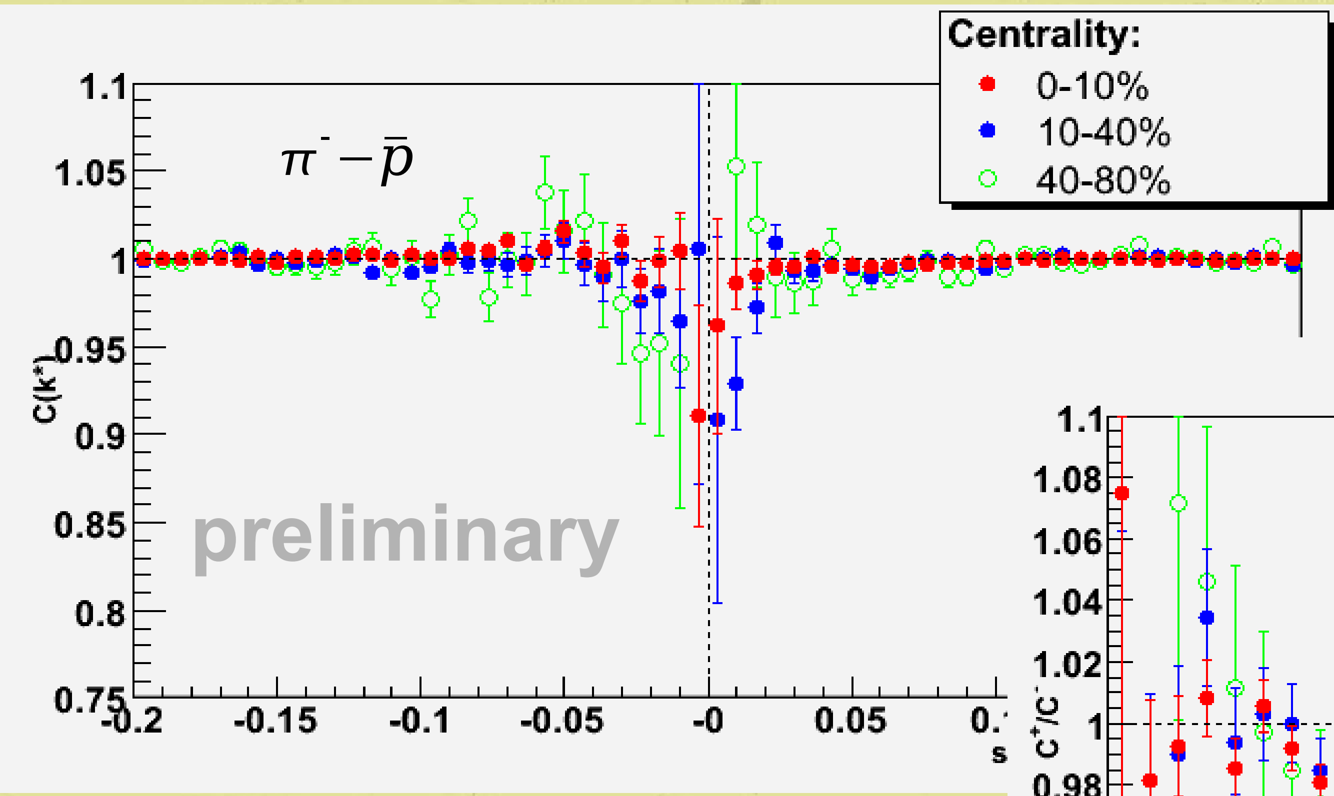
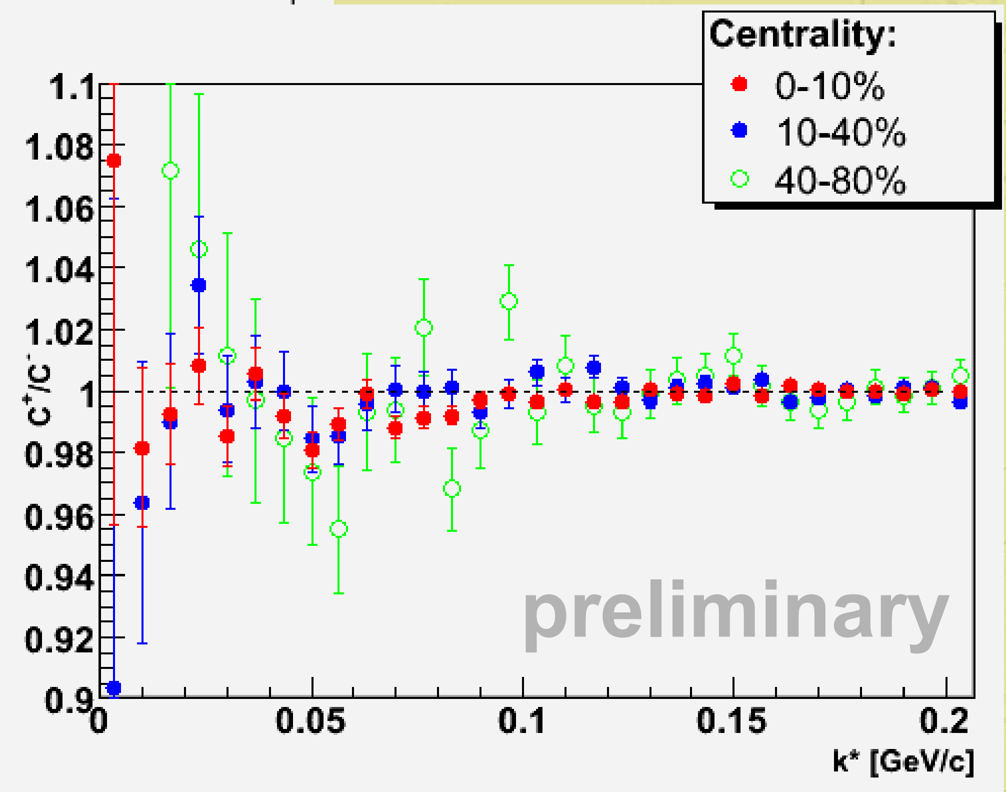
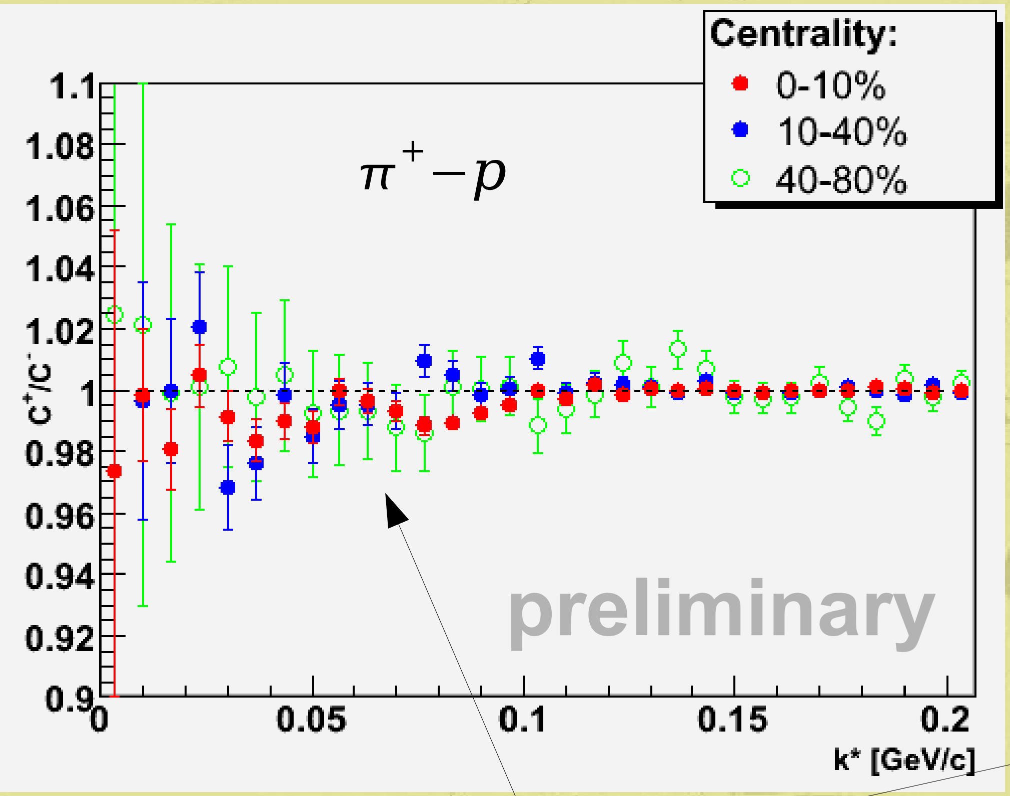
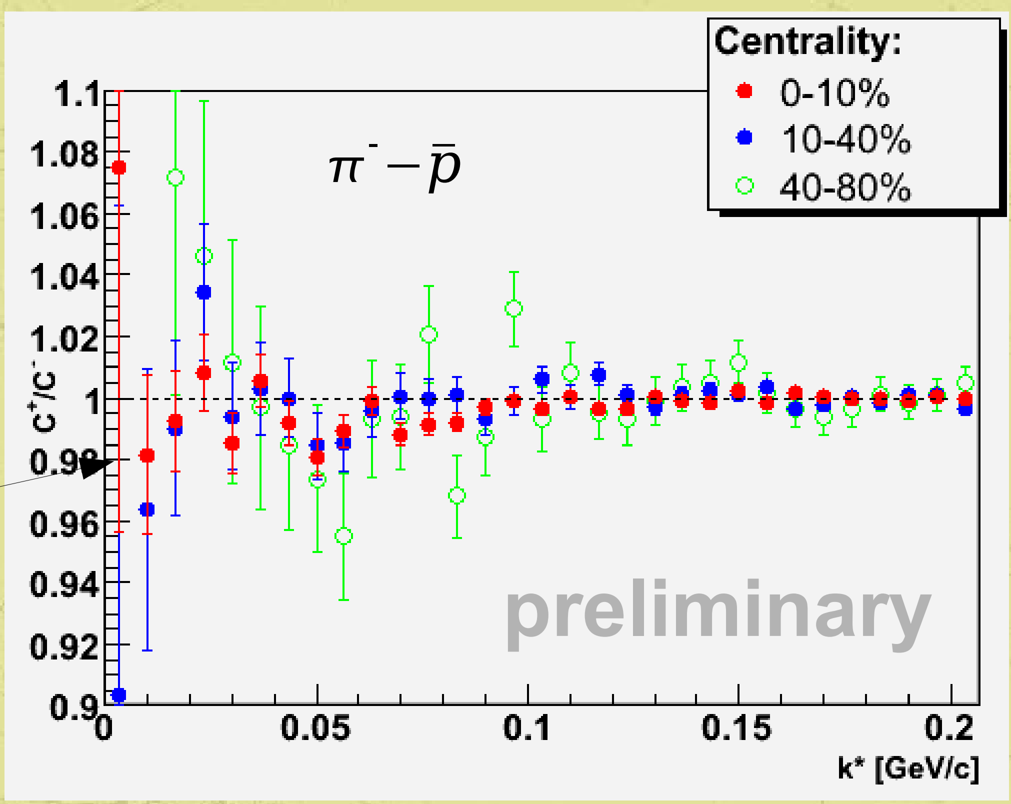




Similar situation is observed for π^- - anti-proton

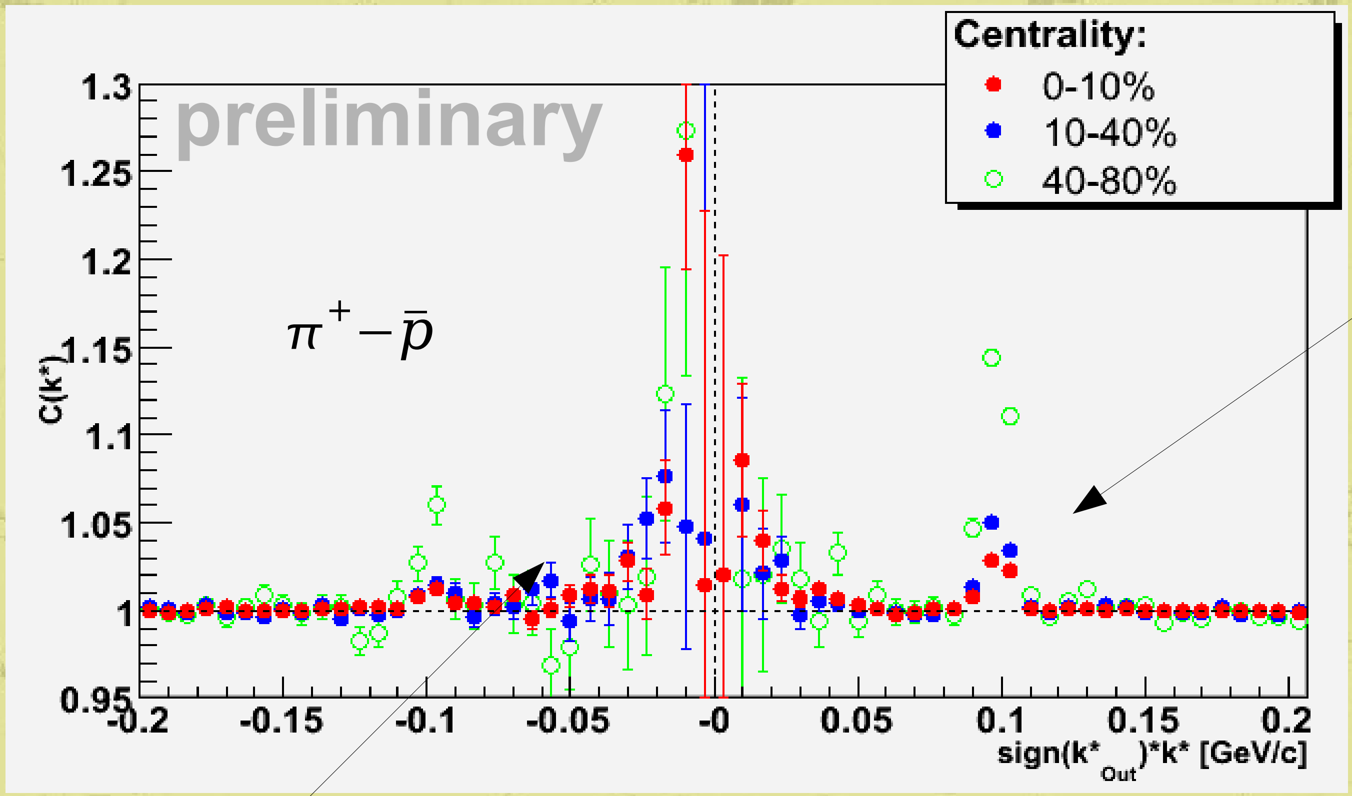
$C^{+}_{side}(k^*)/C^{-}_{side}(k^*)$ as a data quality test





Flat "side double ratio" proves good/correct data selection.

π-p – unlike sign pairs

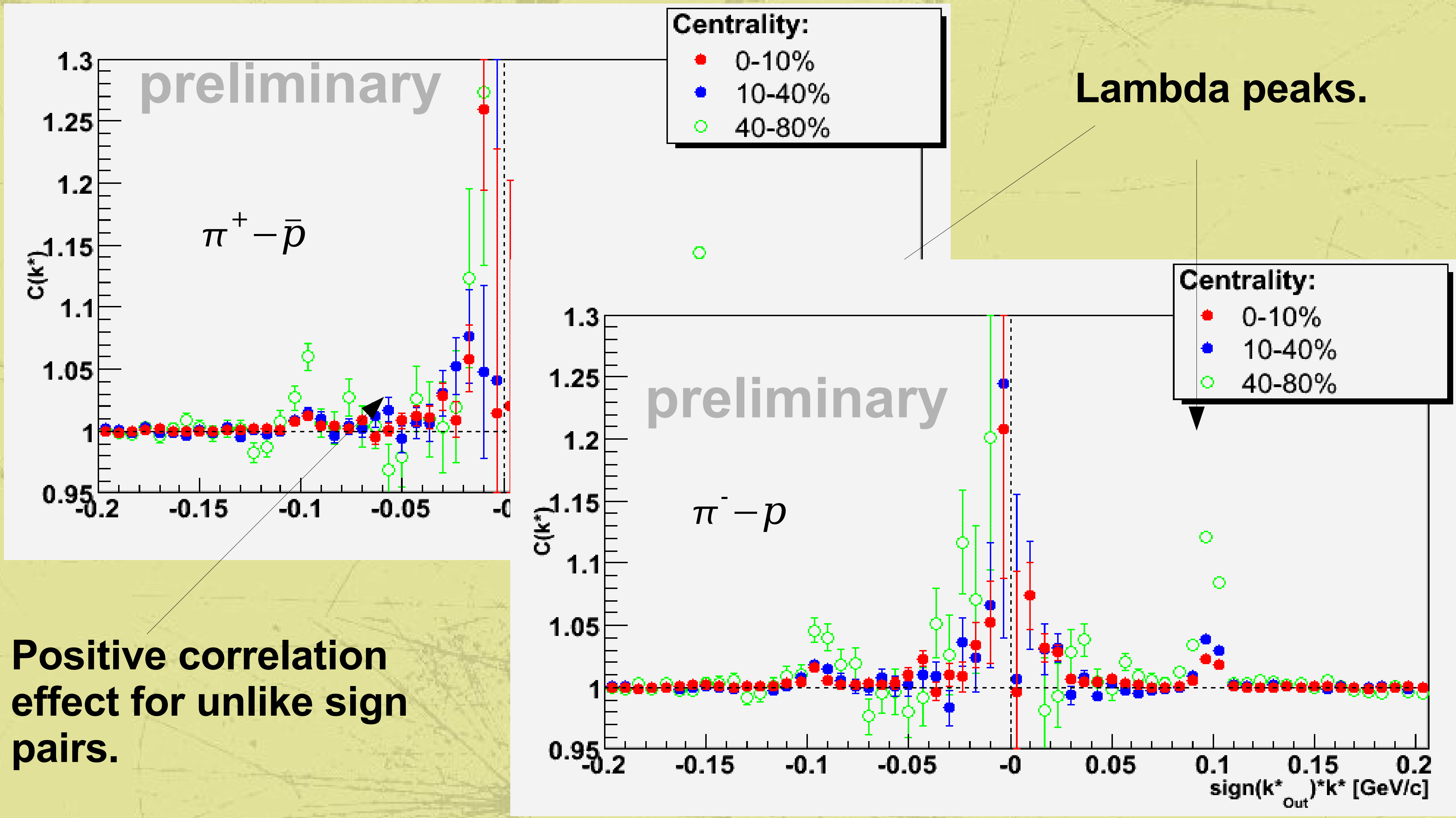


Lambda peaks.

When lambda decay occurs close enough to primary vertex decay products may be, by mistake, treated as primary tracks.

Positive correlation effect for unlike sign pairs.

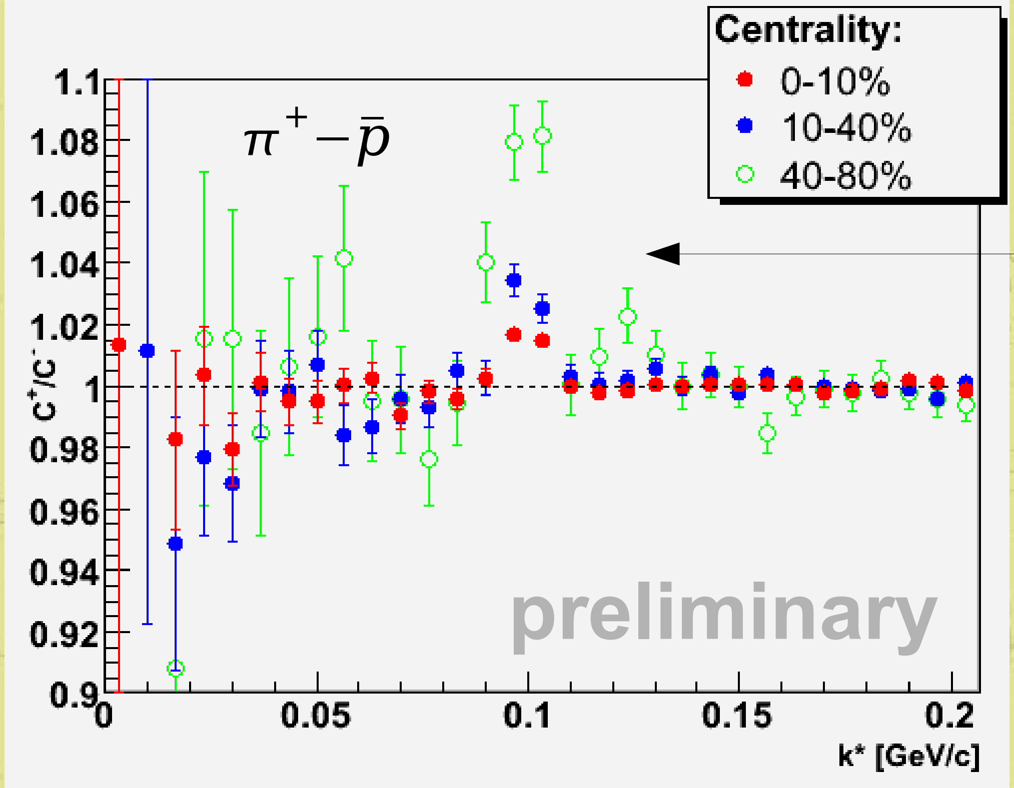
π-p – unlike sign pairs



Lambda peaks.

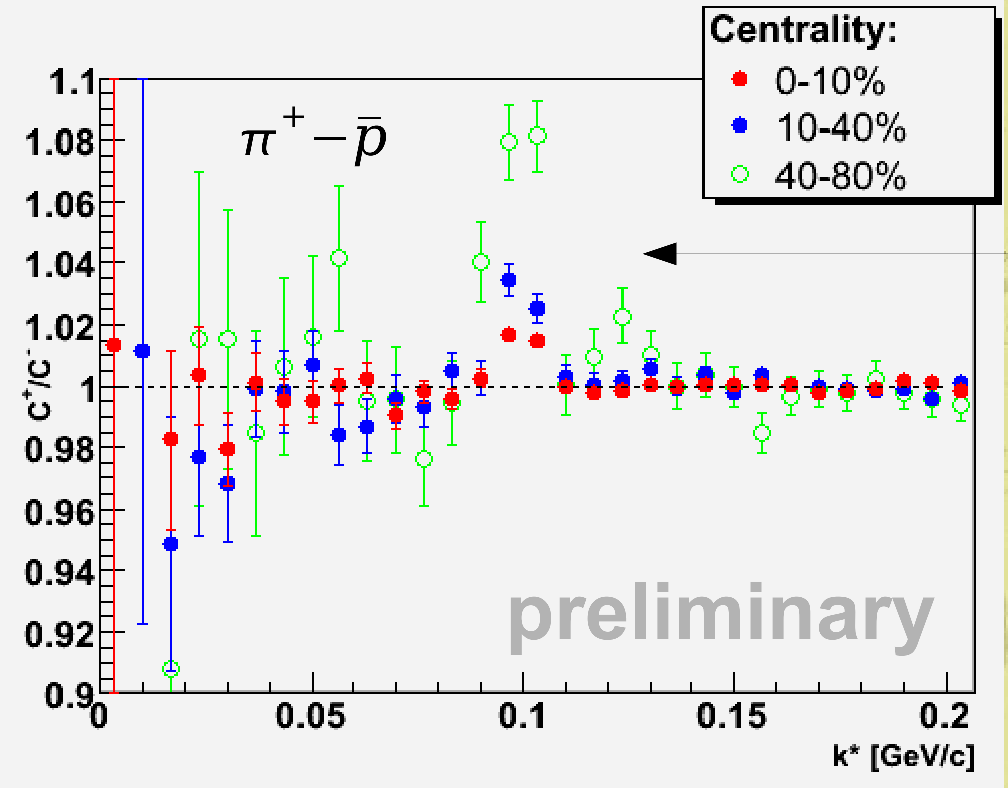
Positive correlation effect for unlike sign pairs.

out "double ratio" for unlike sign pairs



Lambda peak is higher in C^+ than in C^- due to combinatoric background effects (difference in p_T distributions for pairs with $k^*_{out}<0$ and $k^*_{out}>0$).
As a result of that we see lambda in *out* "double ratio".

out "double ratio" for unlike sign pairs



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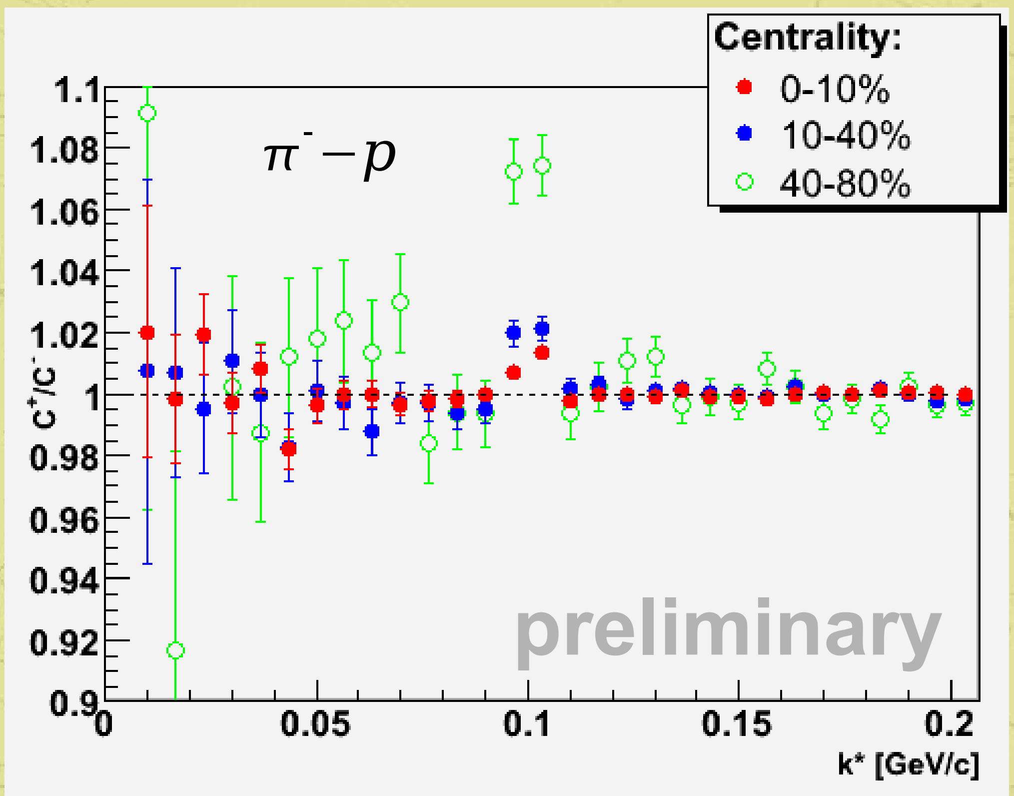


Therminator

- BlastWave model with quasi-linear radial flow velocity profile
- All particles from Particle Data Table
- Decays of resonances
- Model parameters fitted to STAR central data AuAu @ 200AGeV

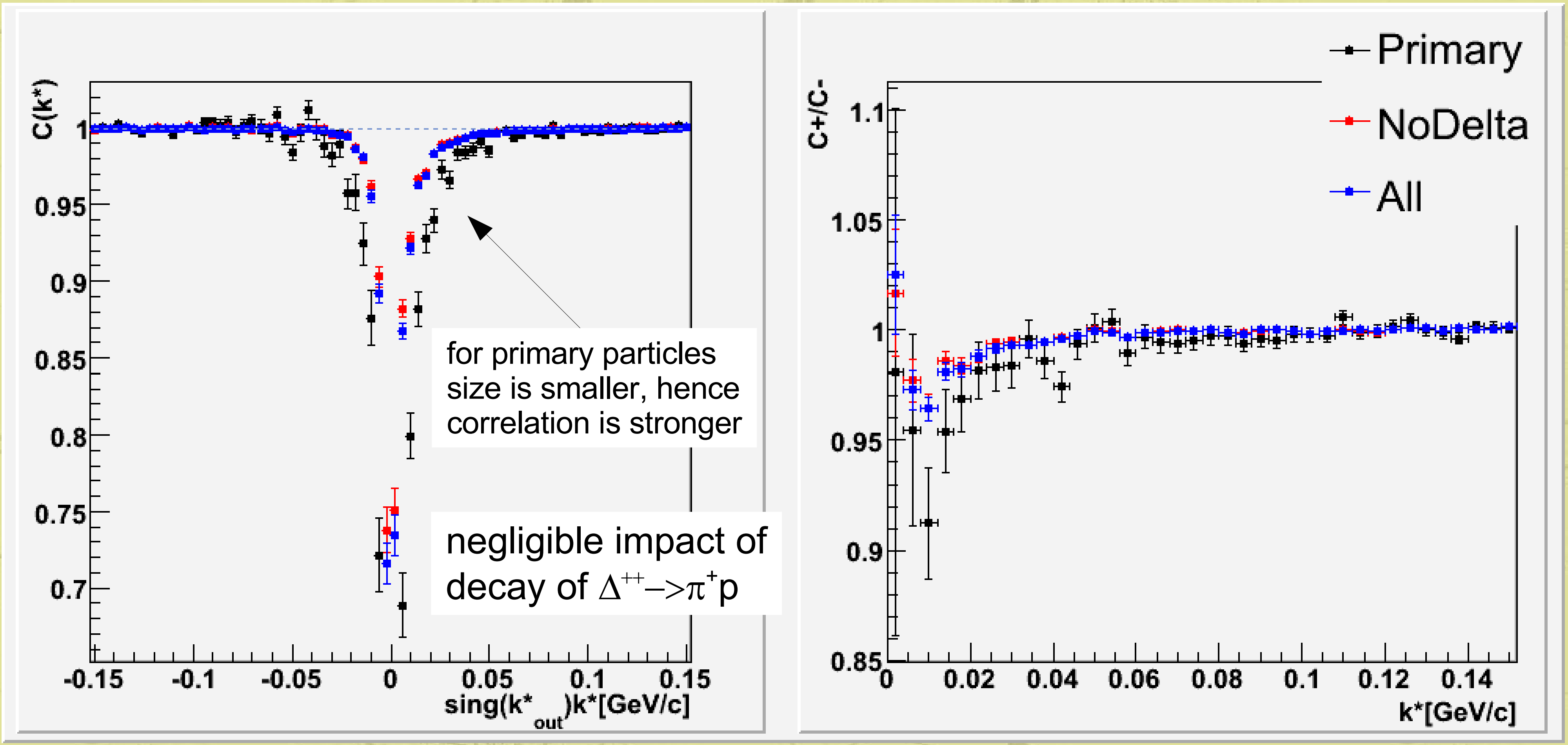
A.Kisiel, T.Tałuć, W.Broniowski, W.Florkowski,
Comp. Phys. Comm. 174 (2006) 669
[nucl-th/0504047]

Motivation for using Therminator

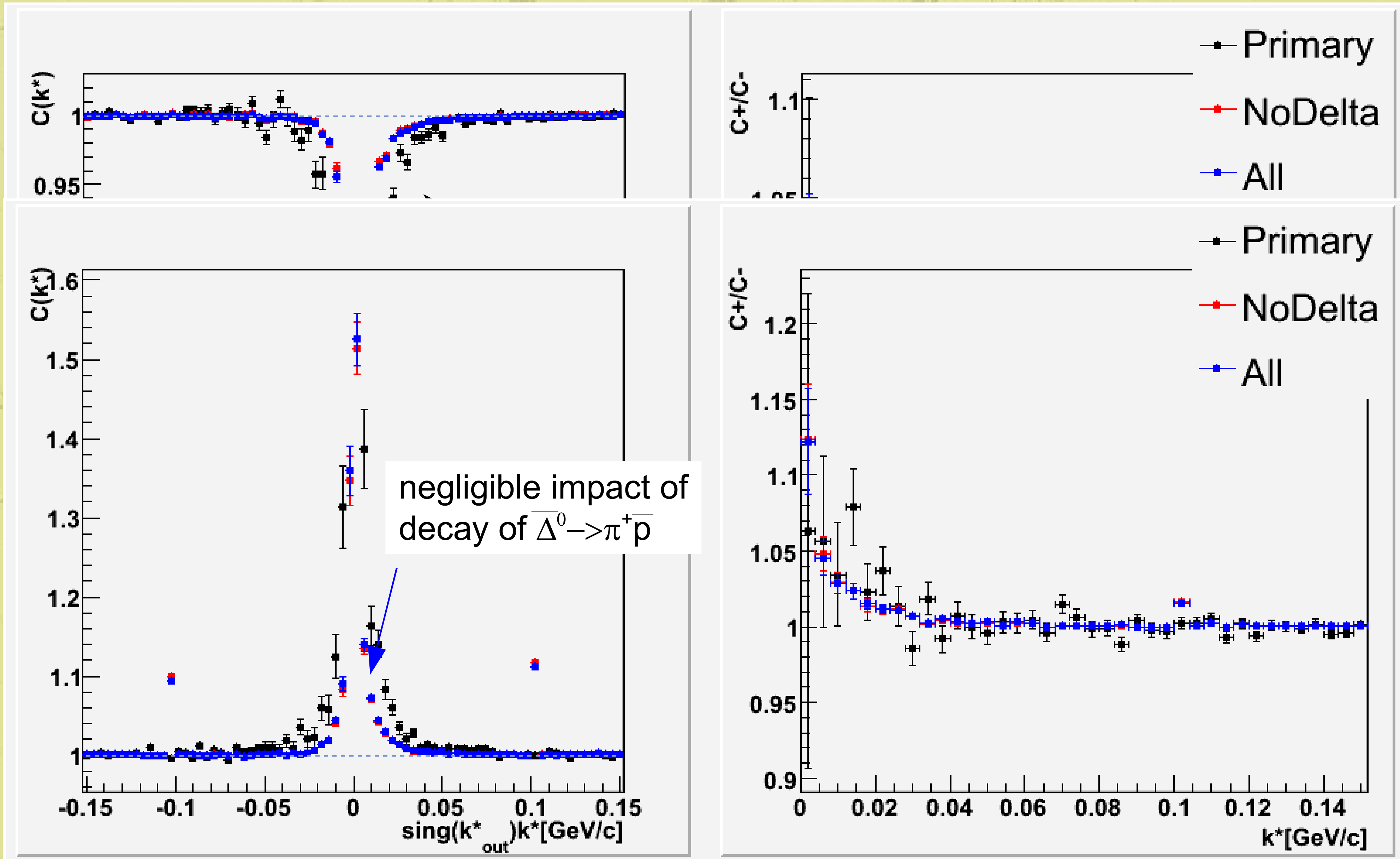
- Our correlation functions measured in the experiment are affected by many effects.
- We want to know how big is the impact of them on our functions
- For example particles coming from decays of delta baryons

$$\Delta^{++}(1232) \rightarrow \pi^{+} - p$$
$$\Delta^{0}(1232) \rightarrow \pi^{-} - p$$
$$\bar{\Delta}^{++}(1232) \rightarrow \pi^{-} - \bar{p}$$
$$\bar{\Delta}^{0}(1232) \rightarrow \pi^{+} - \bar{p}$$

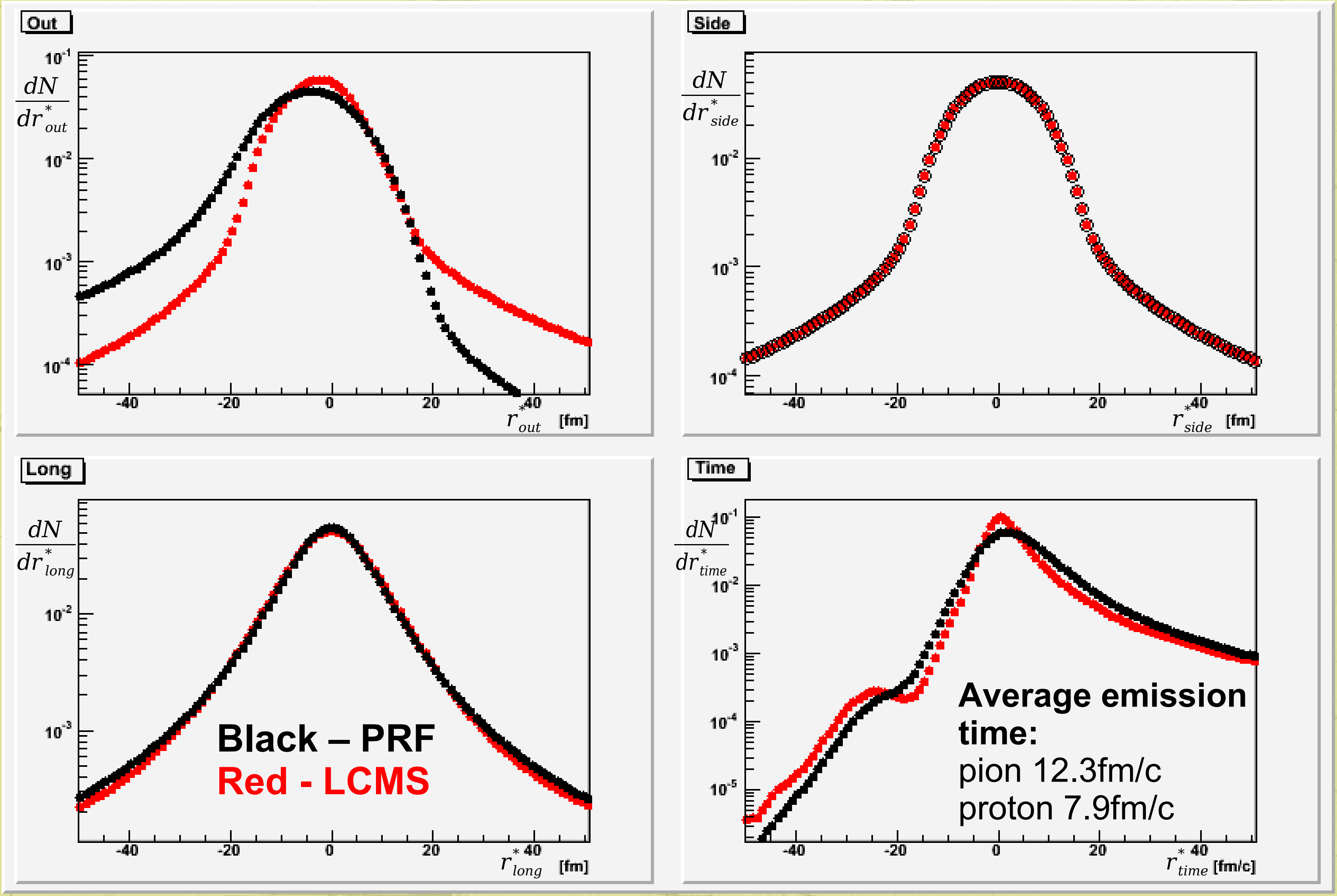
Correlation functions from Therminator



Correlation functions from Therminator

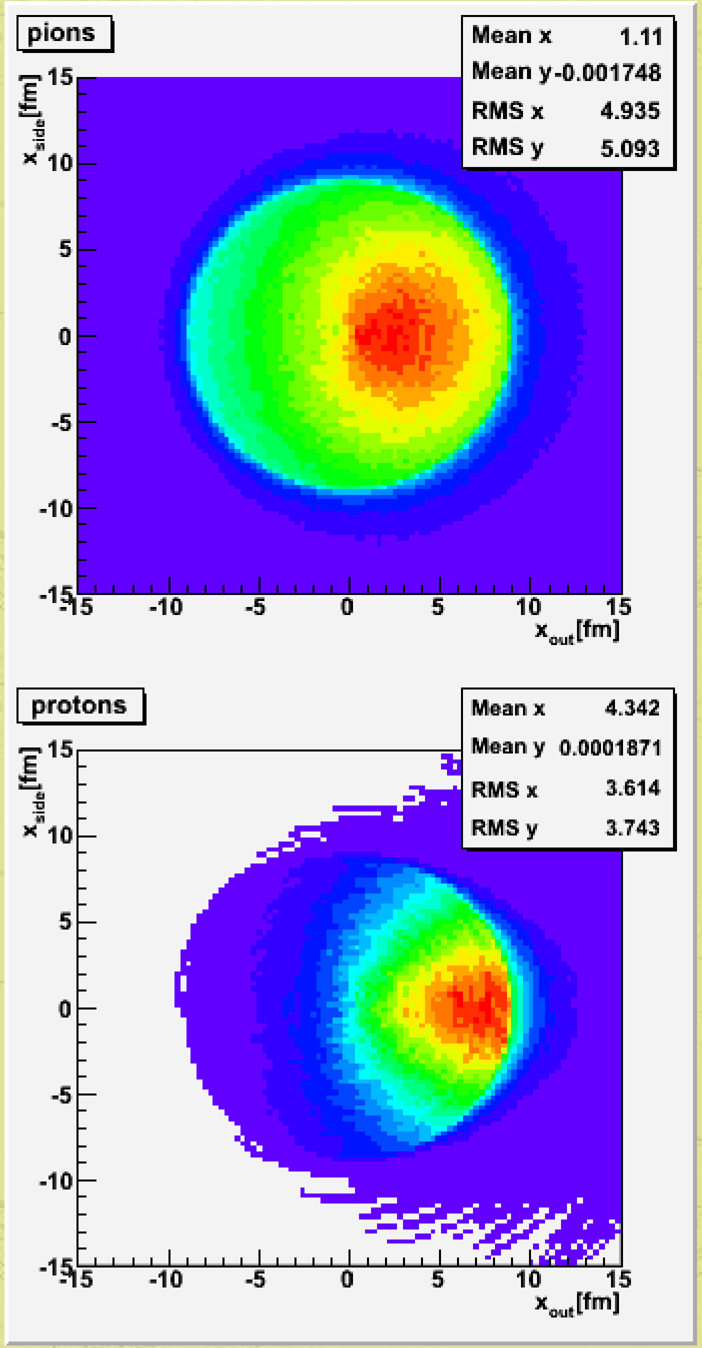


Source distribution

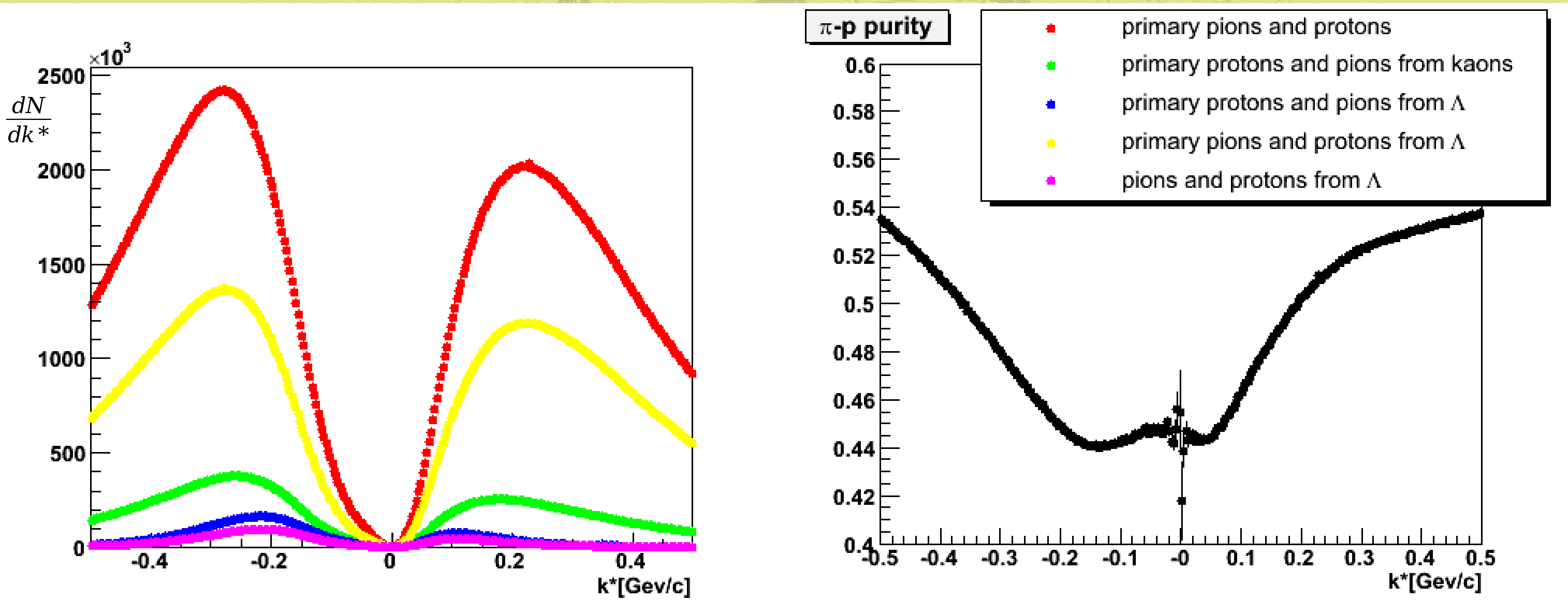


Distribution of emission points of pions and protons

- The average emission points in *out* direction are different for pions and protons
- The average size of emission region is smaller for protons than for pions



Percentage of primordial particles



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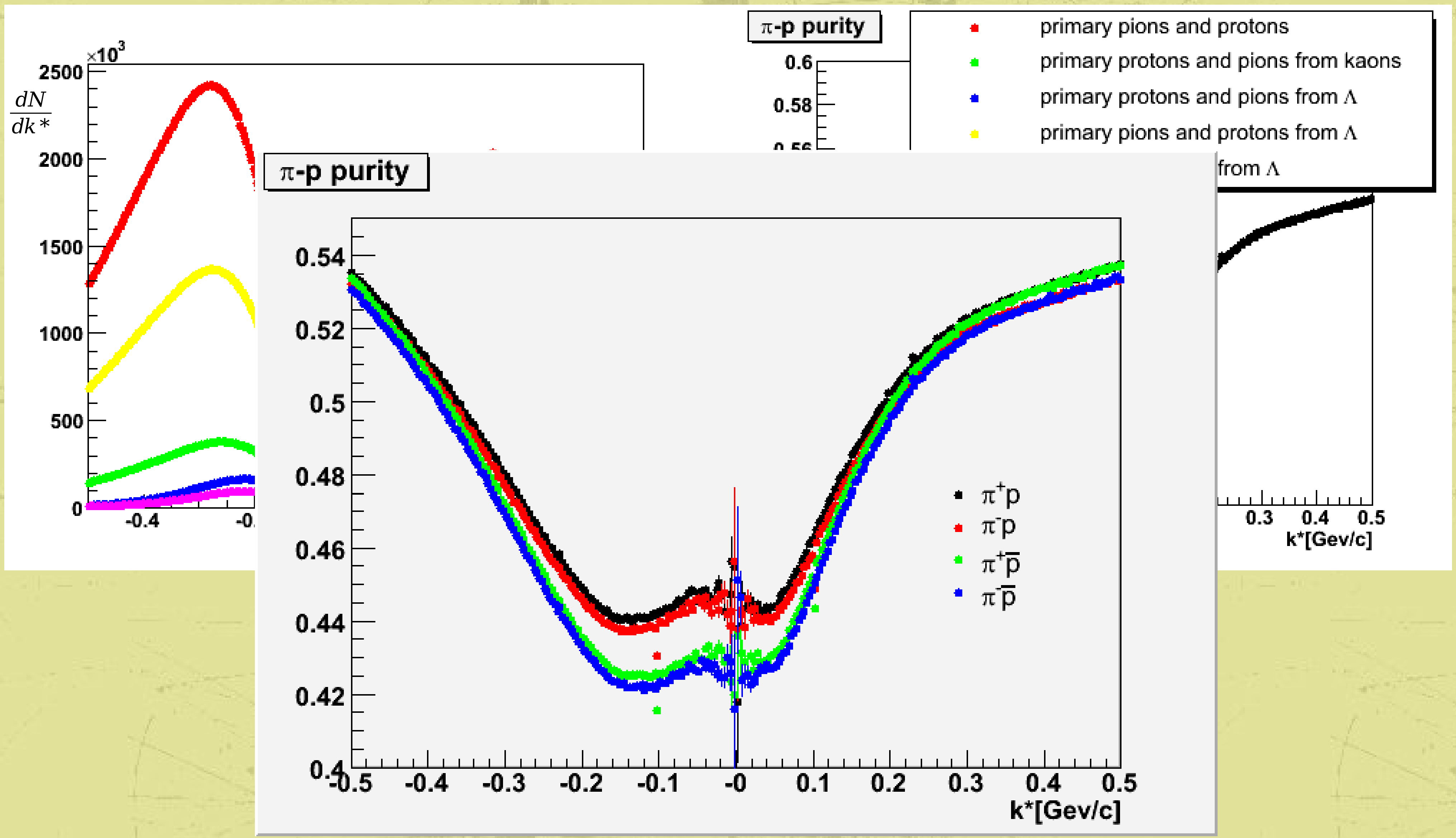
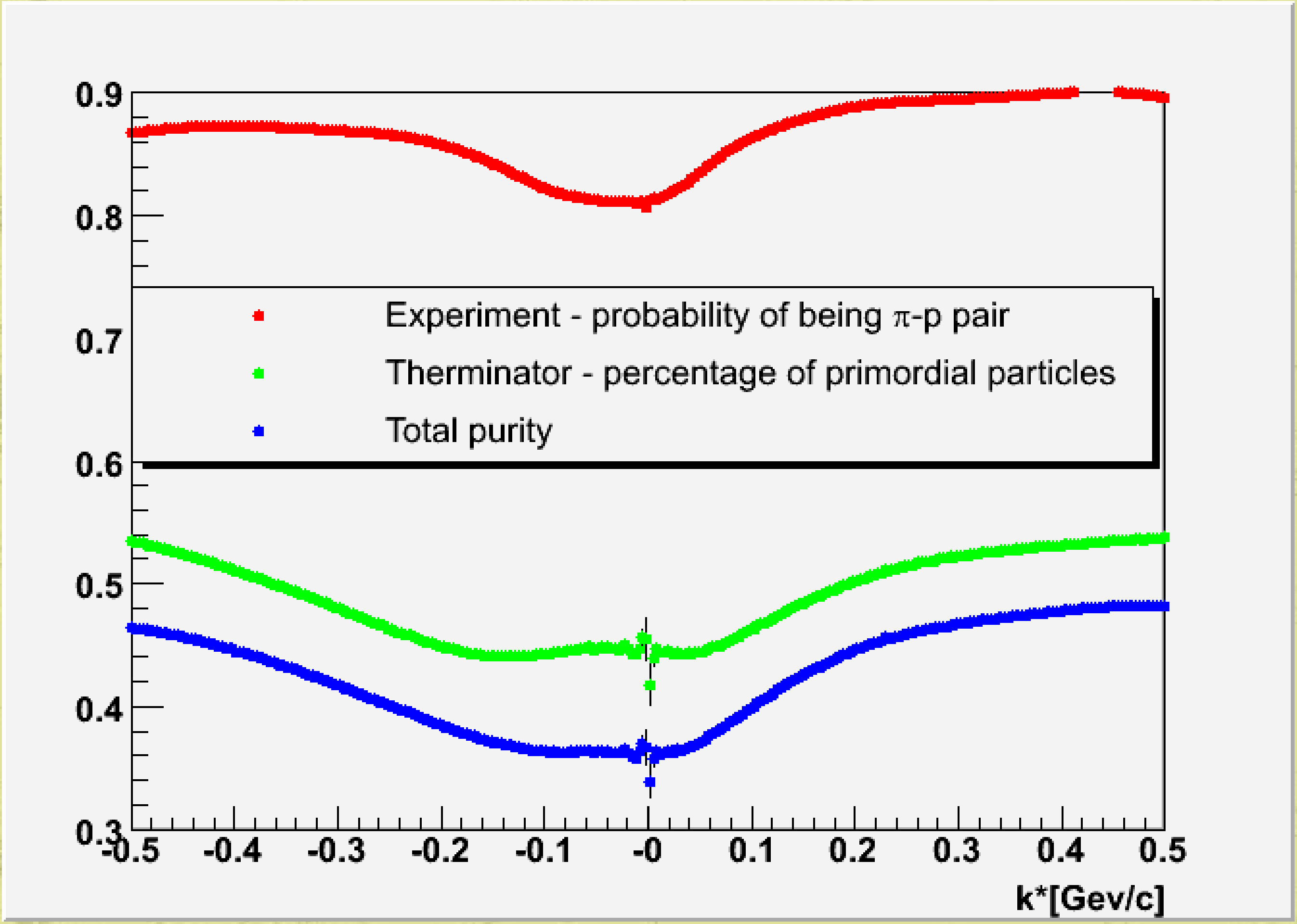


Purity correction

Pair purity is a fraction of pairs that do give a contribution to the correlation effect. Measured correlation function can be corrected according to the following formula:

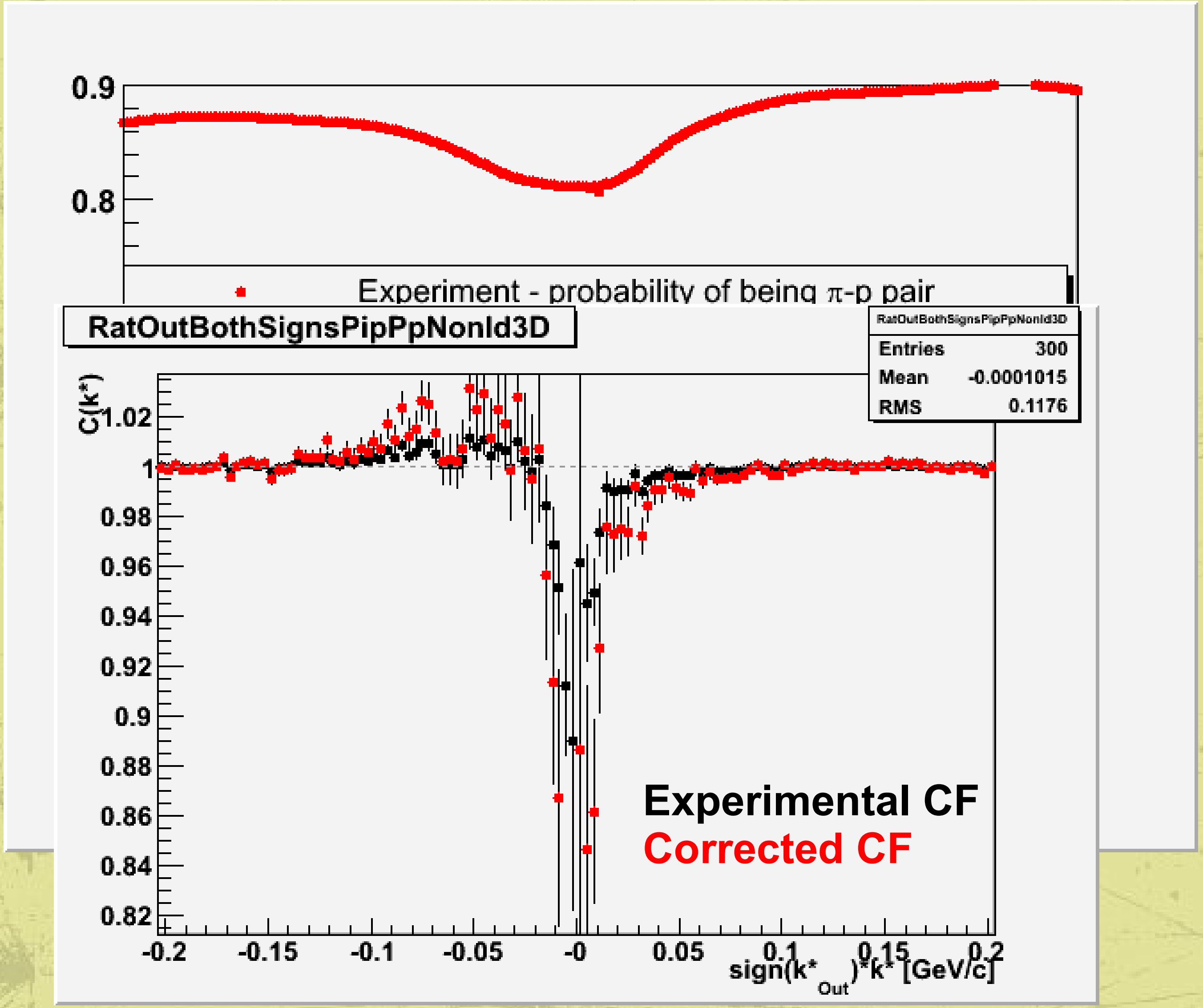
$$C_{real}(k^*) = \frac{C_{measured}(k^*) - 1}{Purity(k^*)} + 1$$



Purity correction

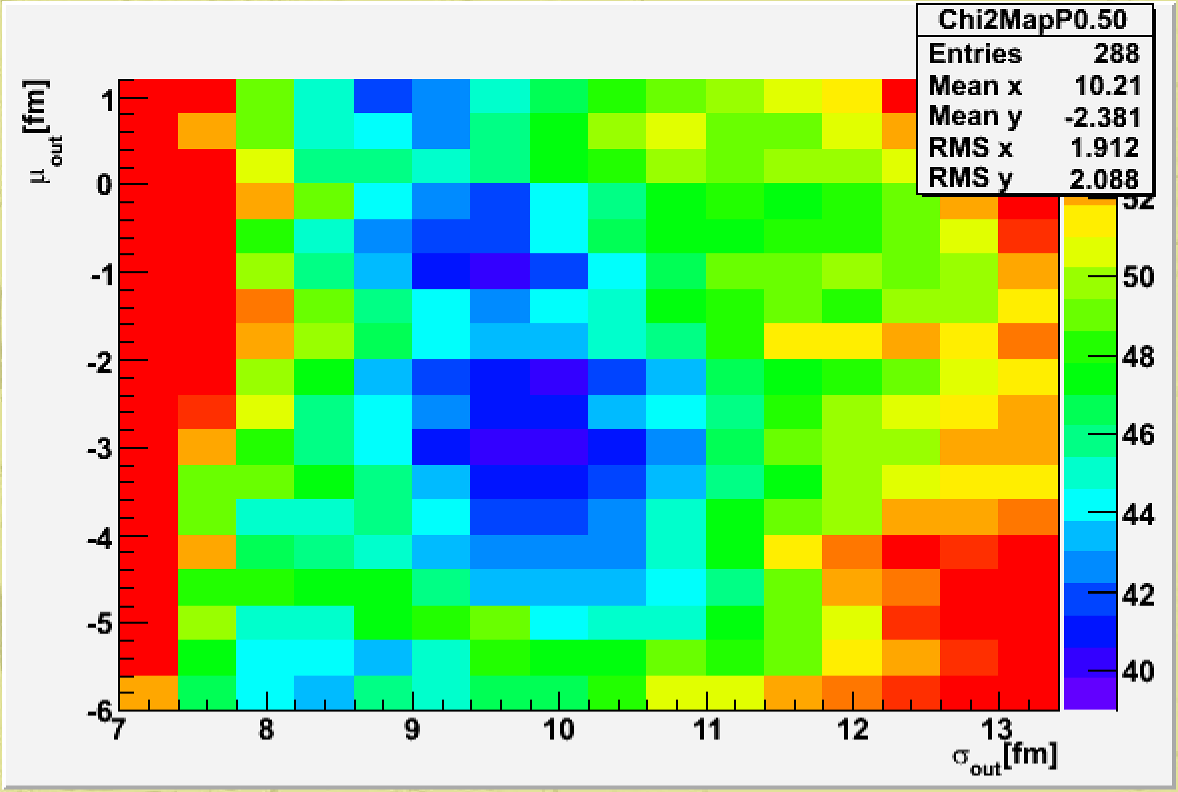
Pair purity is a fraction of pairs that do not give any contribution to the correlation effect. Measured correlation function can be corrected according to the following formula:

$$C_{real}(k^*) = \frac{C_{measured}(k^*) - 1}{Purity(k^*)} + 1$$

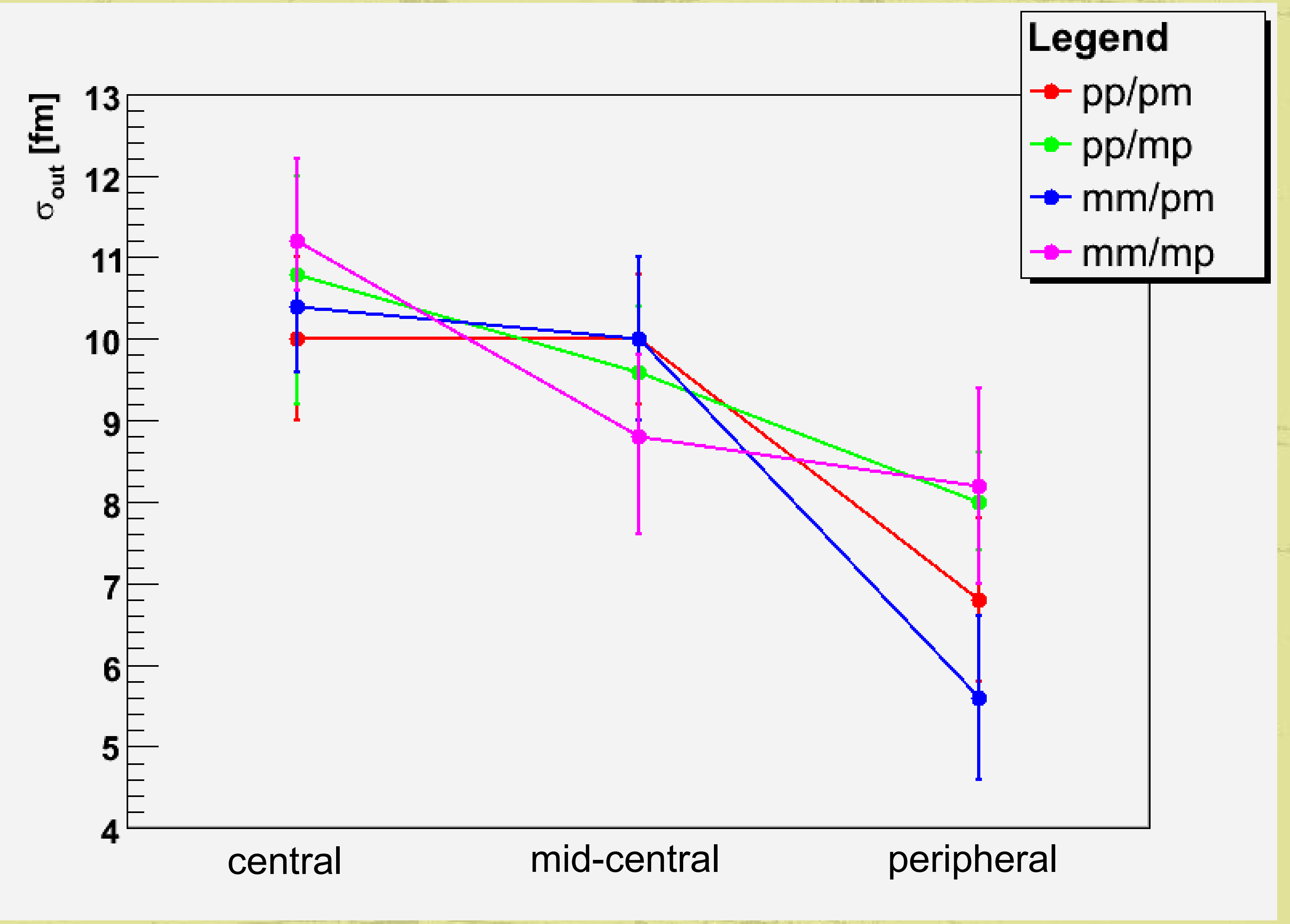


Fit procedure

- CorrFit [A.Kisiel (2004) Nukleonika 49;Suppl 2:s81-s83]
- MC calculation of theoretical functions using experimental pairs and Lednicky's weight method.
- Gaussian source
- pp/pm
  pp/mp
  mm/pm
  mm/mp



Fit results for size of the π-p soure



Conclusions

- Experimental technique of non-id correlation analysis is successfully applied
- We observe emission asymmetry in π-p system
  - average emission point of pions is closer to the center of source then average proton emission point
- Size of the source depends on centrality
- Magnitude of asymmetry is still under study
- Better understanding of the experimental data thanks to theoretical calculations with Therminator

Thank you for your attention:-)